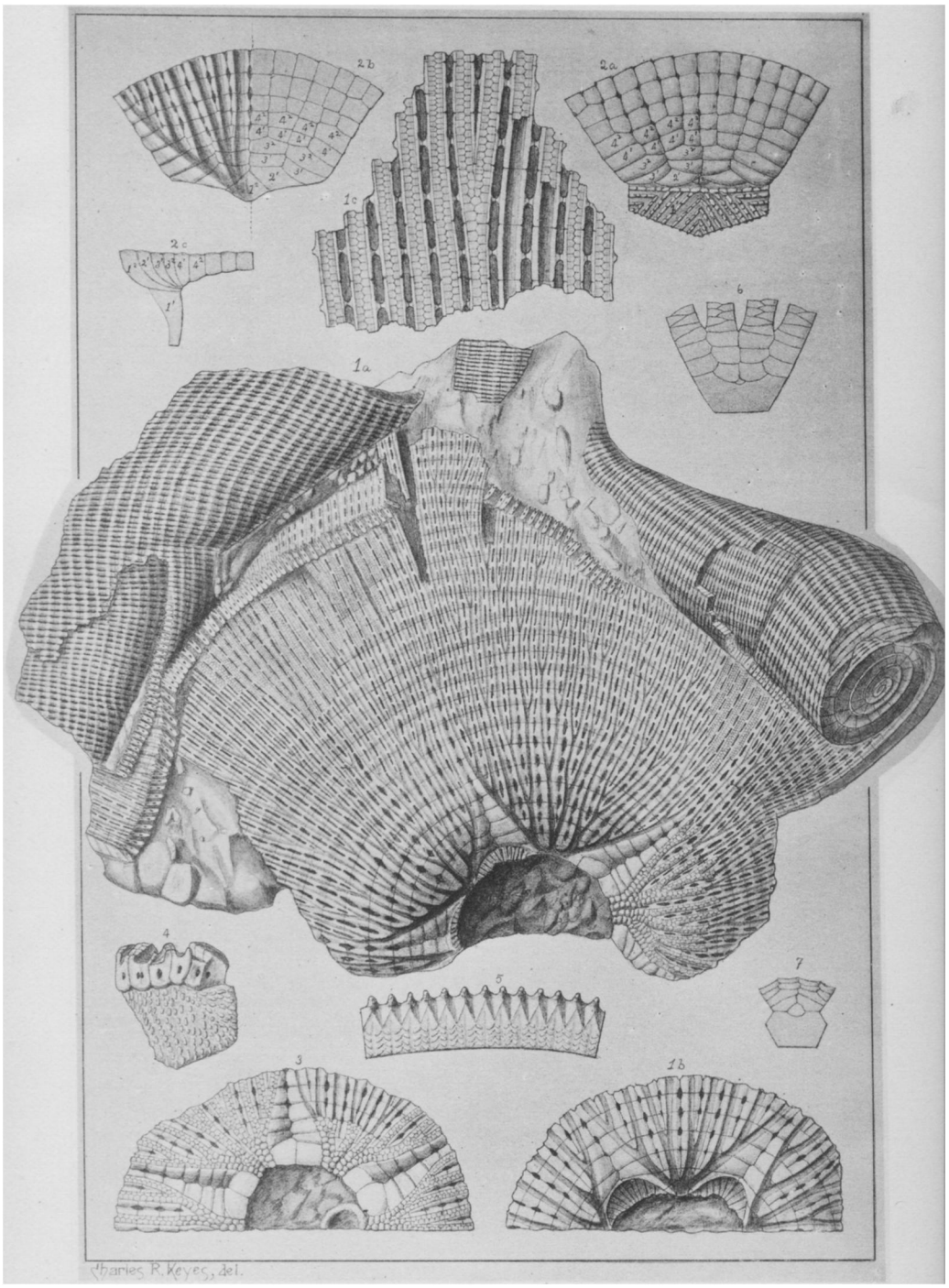
CROTALOCRINUS: ITS STRUCTURE AND ZOOLOGICAL POSITION.

BY CHARLES WACHSMUTH AND FRANK SPRINGER.

The type of Crinoids that has been described under the name *Crotalocrinus*, is one of the most extraordinary yet brought to light from palæozoic rocks. Its net-formed radial appendages, so widely different from those of any other known Echinoderm, and resembling rather the fronds of a Bryozoan than the arms of a Crinoid, have long made it a puzzle to naturalists, and the efforts of all writers up to the present time—ourselves included—have contributed but little toward any satisfactory determination of its systematic relations. Though so highly differentiated in its structure, the genus is confined to the upper Silurian, so far as known. It has been found in the island of Gothland, Sweden, where it was first noticed by Hisinger in 1828, and afterwards described by him as a *Cyathocrinus* in 1837. It was also found at Dudley, England by Parkinson in 1808, who called it the *Turban* or *Shropshire Encrinite*; and it was redescribed by J. S. Miller in 1821, as *Cyathocrinus rugosus*. No trace of it has ever been discovered at any other locality. Good specimens are rare and difficult to obtain, so that the facilities for its study, outside of the countries where it occurs, have hitherto been practically *nil*.

The arm structure was not understood until 1854, when Johannes Müller figured and described under the name *Anthocrinus Loveni* the principal Swedish species, although Austin had established the genus *Crotalocrinus* in 1843, for the English form, without figure and with a very meagre description. Angelin's elaborate work on the Swedish Crinoids in 1878, contained numerous beautiful figures of apparently perfect specimens, and seemed to give the most ample illustrations of every part elucidating the structure of this curious fossil. Upon these descriptions and figures, and without any opportunity to study even a single specimen, we prepared our description of the genus, and discussions relating to it, as they appeared in Part III of our Revision of the Palæocrinoidea.

Not long after the publication of this work, we found reason to believe that our interpretation of the structure and affinities of *Crotalocrinus* was erroneous, and that much of what we had written on the subject was altogether worthless. During a visit of one of us to Europe last winter, he had an opportunity of examining the



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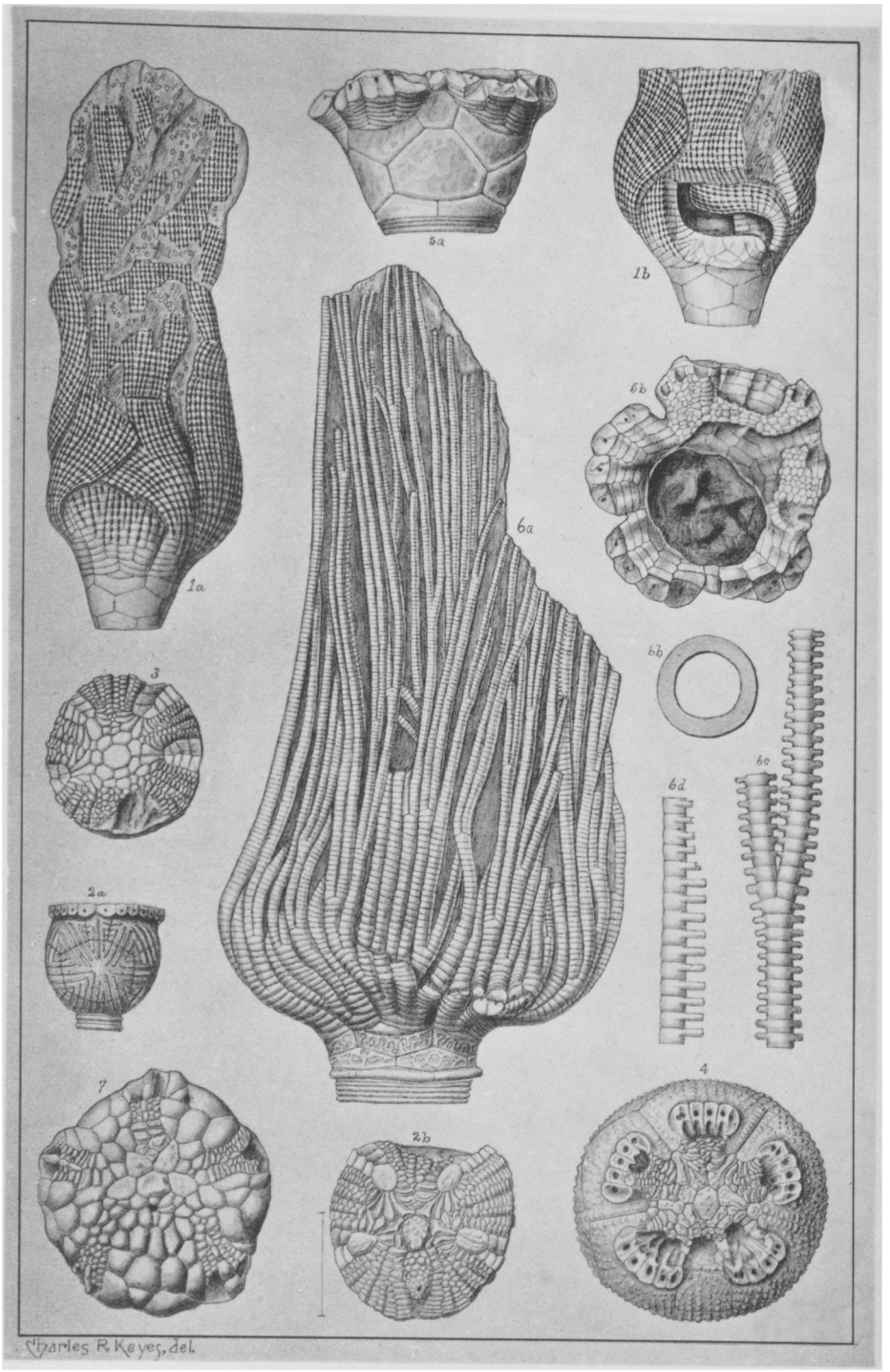

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best known English specimens, in the British Museum and other collections, and by considerable effort succeeded in obtaining some excellent material for more detailed study, both from England and Sweden. Besides this we have enjoyed the unexpected privilege of studying a number of the original specimens used by Angelin. For this we are indebted to Dr. Gustav Lindström, Curator of the Palæontological Department of the National Museum at Stockholm, who on being informed of our perplexity regarding this genus, upon his own motion, sent us these and other specimens, with liberty to study them at our leisure; and also furnished us most important information in the way of drawings and observations upon other specimens. It was an act of thoughtful kindness for which we find it difficult to adequately express our gratitude, and if this paper shall be found to be of any value to our fellow naturalists, it will be in a very large measure due to the facilities thus generously afforded us.

In the Revision of the Palæocrinoidea, Part III, pp. 140–143, we referred *Crotalocrinus* and *Enallocrinus* to the Articulata, and at various places (pp. 18, 19, 56, 64, 65) based some of our arguments as to the character of this suborder upon the supposed structure of these two genera. On pages 18 and 19 of Part III, we stated that "In the Crotalocrinidae, which include *Crotalocrinus* and *Enallocrinus*, the whole ventral surface, in what appear to be the best preserved specimens, is composed of strong, convex plates, without definite arrangement. In these specimens there is no central plate, nor proximals, nor traces of ambulacra (Icon. Crin. Suec., Pl. VII, fig. 3a; Pl. VIII, figs. 6, 7, and Pl. XXV, fig. 2.); there are, however, other figures of Angelin, apparently of a closely allied species (ibid. Pl., XVII, fig. 3a), in which the plates paving the ventral surface are much more delicate, and consist of a central plate, large proximals, and several rows of covering pieces, without the intervention of either anambulacral or interradial plates. It would be difficult, with the utmost stretch of our imagination, to recognize in the former figures either proximals or central piece, which, as admitted by Carpenter, are present in all these crinoids, and we think there can be little doubt that the two sets of figures represent different parts of the animal, the one the disk, the other the vault, and that the one covered the other. A similar opinion was evidently entertained by Zittel (Handb. d. Palaeont. I, p. 357), who stated that *Crotalocrinus* possessed five 'grosse Oralplatten, bald unter der Decke, bald äusserlich

sichtbar.' According to our interpretation, the calyx of the Crotalocrinidae extends ventrally to the oral pole, and the ambulacra, central piece, and proximals are subtegminal, covered by interradial plates, which extend out to the lower rows of covering plates and side pieces (Icon. Crin. Suec., Pl. VIII, fig. 6, and Pl. XXV, fig. 2). A similar condition probably prevailed in the Ichthyocrinidae, with which the Crotalocrinidae have close affinities."

As our reference of these genera to the Articulata was based exclusively upon the figures, especially those of Angelin, it will be well to examine them now in the light of the knowledge we have since obtained. The only figure of those quoted that gives the vault structure correctly, is fig. 3a, on Plate XVII. It shows very plainly four large proximals and a large plate toward the posterior side, which, according to the terminology we then employed, we regarded as a central plate. The proximals are elongate-nail-shaped, and two of them touch the incurved ends of the upper faces of the first radials, while two others abut against a small interradial plate, and the larger posterior plate against small plates around the anus. Within the re-entering angles, between every two of the large plates, there are several series of small pieces ramifying toward the arm openings and laterally connected. Dr. Lindström has sent us a very carefully prepared drawing of a specimen which he thinks is the original of the above mentioned figure. This is reproduced by us on Pl. XX, fig. 4. The structure appears substantially the same, but the details are better defined in this figure than in the former, showing that the proximals touch the first radial only at one side, while at the other sides one, two, or three small interradial plates are interposed. Within the five re-entering angles formed by the five orals (central plate and four large proximals),* rest five comparatively large radial-dome-plates, which are followed by several rows of small alternating pieces. That the latter are covering plates which were continued along the arms is well shown in both figures.

A totally different structure was exhibited by figs. 6 and 7, Pl. VIII, of *Crotalocrinus pulcher*, and by fig. 3*a*, Pl. VII, and fig. 2 Pl. XXV, of *Enallocrinus scriptus*, all purporting to show the plates of the ventral side completely. In all of these figures the arrange-

* The so-called "proximals" and "central plate," as we have shown elsewhere, are now regarded by us as representing the five oral plates, the central plate being the posterior oral, modified and displaced by anal structures.

ment of the plates covering the visceral cavity is extremely irregular, scarcely any two plates being alike. There is neither a central plate, nor anything that might be compared with the four large proximals, and no plates corresponding to, or which might be identified as covering plates until the region of the arms is reached. In Pl. VIII, fig. 6, the plates appear ornamented by small nodes up to the second bifurcation of the ray, and a similar ornamentation covers the anal structure, of which portions are visible. This ornamentation is so marked, and gives to this part of the figure such a totally different aspect from the higher branches of the rays, in which it is entirely absent, that we regarded it as a vault, from underneath which the covering plates emerged. The whole figure gives one the impression that it was made from a very perfect specimen, in which the minutest details of structure were exceptionally well preserved. The other figure–7–on the same plate exhibits a similar vault, but with less elaboration of ornament and surface details. Covering plates are here visible only upon the parts which extend beyond the limits of the calyx, nor is there any trace of proximals or central plate.

Figure 3*a*, of Pl. VII, which is said to represent "*pars perisomatis ventralis*" of *Enallocrinus scriptus*, shows a complete uninterrupted covering of the whole ventral surface of the calyx and portions of the rays. As in the other figures, the plates are wholly wanting in definite arrangement, no summit plates can be discovered, and the covering pieces, as before, begin at the periphery of the calyx.

Another figure of the same species, apparently from a most beautifully perfect specimen, to judge from the drawing, is given on Pl. XXV, fig. 2. It is stated in the explanation of the plate to be the same specimen as fig. 1, seen from above, and there is no reference to any imperfection or restoration. It appears to show all the plates of the ventral covering from the center of the summit to a long distance out upon the arms. In this figure, as in the preceding, there is a complete absence of any regular plan of arrangement among the plates forming the ventral part of the calyx. It would be impossible by any degree of imagination, to identify among them anything like summit plates or covering pieces, the latter commencing beyond the limits of the calyx. The plates are generally represented as nodose, and those toward the middle as the largest, but beyond this there is nothing in the figure to distinguish any of them.

It was upon the information derived from these figures that we based our conclusion—hasty as it may have been—that there were two integuments in these genera, one above the other; one representing the perisome containing the ambulacra, the other a vault of irregular pieces, and to some degree pliable.

We could not see how two such totally different structures as those shown by Pl. XVII, fig. 3*a*, and Pl. VIII, fig. 6, could represent the same elements in one and the same genus, and we therefore adopted the idea of a double covering as the only solution we could find, although after considerable hesitation, feeling that such an arrangement was quite anomalous, and without a parallel elsewhere. We were also influenced in no small degree by the fact that Prof. Zittel, who had the opportunity to see the Swedish collections, interpreted the structures in a similar way.[1]

We could not, of course, imagine that such magnificent figures as are represented in Angelin's work[2] in the absence of any explanation to that effect, could be wholly imaginary as to the most important parts of the structures illustrated. The fact is, however, as we now know, that all these important figures are to a large extent fictitious; that the middle portions of them, where the summit plates and covering pieces of the vault should have been found, were not shown in the specimens at all, but were filled in by the artist according to his own notion of their probable structure.

The only specimen in the National Museum at Stockholm which shows any part of the vault structure of *Crotalocrinus*, aside from the original of fig. 3*a*, Pl. XVII, has been sent to us for examination. It is evidently the original from which fig. 7, Pl. VIII was composed; for Dr. Lindström informs us that there is no other which can be regarded as the type of that figure. It shows the lanceolate areas and covering plates along the arms beyond the calyx very well, but

1 Handb. d. Pal. Vol. i, p. 357.

2 It is but justice to the distinguished Swedish palæontologist to remark that his work on the Crinoids of Sweden was not complete at the time of his death. His descriptions seem to be rather preliminary notes made for his own use, preparatory to a more detailed study. These were collected after his death and published, together with twenty-nine plates illustrating them, under the direction of the Royal Academy of Sciences of Sweden. It is not strange under such circumstances there should be errors, and in pointing out some of them in this paper we have no intention of discrediting a work which has been of great service to palæontology by bringing to notice one of the most magnificent crinoidal faunae ever discovered.

the middle is entirely broken away, leaving, however, partially in place a few plates around the anal opening. There is nothing in the specimen from which the form and arrangement of the summit plates could be even inferred.

Of fig. 3*a*, Pl. VII, Dr. Lindström writes: "The figure is not correct. The central plates are totally wanting, as in *all* specimens of *Enallocrinus* I have seen, and there are no vestiges left to infer its true nature. There can be no satisfactory drawing made of it."

Among the specimens sent us from Stockholm was one labeled 'VII 3," which we suppose to be one of the originals from which Angelin's Pl. VII, fig. 3*a*, was in part deduced. We have figured it to illustrate our description of *Enallocrinus* (Pl. XX, figs. 6*a*,*b*), and we learn that there are no other specimens of *Enallocrinus* which show any more of the summit than this.

As to fig. 2, Pl. XXV, Dr. Lindström writes: "I cannot conceive how such a drawing could have been executed out of it. The upper side is so badly preserved that no good figure can be taken."

The original of the splendid figure 6, Pl. VIII—*Crotalocrinus pulcher*—which was from the Marklinean Museum at Upsala, cannot be found, and we are therefore unable to give any particulars about it. We have not the least doubt, however, that this figure, which is stated to be enlarged (how much, we do not know), is even a greater fiction than the others. In our own specimen of *C. pulcher* from Sweden (Pl. XIX, figs. 1*a*, *b*, *c*), we succeeded in exposing enough of the summit, while cleaning around the ventral tube, to show that it is composed of covering pieces, interradials and summit plates, just like the Cambridge specimen (Pl. XIX, fig. 3).

These four figures, thus shown to be to a large extent incorrect and misleading, were the ones on which we entirely relied in the statement above quoted from Part III of the Revision. That statement was critized by Dr. P. Herbert Carpenter in a paper "On the structure of Crotalocrinus," in which he asserts, that "in their [our] statement that 'there is no central piece, nor proximals, nor traces of ambulacra' in the figures of *Crotalocrinus pulcher* and *Enallocrinus scriptus*, they appear to me to be seriously in error."[1]

It must be observed first, that in this portion of the paragraph quoted, we were speaking solely of the vault proper, and not of the rays and arms beyond the limits of the calyx. We distinctly refer to the existence of "covering plates and side pieces to which

[1] Ann. and Mag. Nat. Hist., 1886, p. 339.

the interradials extend" (p. 19), and on page 143, in our diagnosis of the *Crotalocrinidae*, we stated: "Ambulacral furrow deep, ramifying with the arm branches, covered by alternating plates, and bordered by side pieces." The ambulacra and covering pieces over them, *in the arms*, which those figures all show, were therefore clearly recognized by us always.

It is worthy of note, however, that Carpenter, while pronouncing us "seriously in error" in saying that there is no central piece, nor proximals, nor traces of ambulacra in the figures of Angelin above referred to, does not undertake to point out the presence or location of either one of those elements upon the figures in question, although he expresses on p. 403 his belief "that the small covering plates of *Crotalocrinus rugosus* are the representatives in a smaller crinoid* 'of the large rigid plates' shown in figures 6 and 7, * * * * while I shall also continue to believe, until the contrary is demonstrated, that the central plate and proximals are among the irregular pieces occupying the oral pole in the originals of these two figures." Neither does he inform us that the figures themselves are totally incorrect and fanciful, although at that time fresh from an examination of the type specimens at Stockholm.

Carpenter says (*op cit.* p. 399) that "while the summit plates are clear and well defined in some species and genera, there are other closely allied forms, in which these plates are almost or entirely undistinguishable among the large number of plates to be found in the vault. I will only mention one instance in illustration of this statement, viz. *Cyathocrinus iowensis* and *C. multibrachiatus*, both of which are figured by Wachsmuth and Springer (Revision Part. III, p. 65, Pl. IV, fig. 6, and Pl. V, fig. 7), the former with, the latter without any distinct summit plates."

These two figures, as the explanation shows, represent specimens in which the summit plates were in an imperfect condition, indicating a process of resorption or modification going on, and were expressly given for the purpose of illustrating this fact. The summit plates, as we stated on page 49 (Rev. Pt. III), "are in their arrangement, as a rule, very regular, and only disturbed by the anal tube." We stated further on the same page that the apparent disturbance in some species with a large number of arms was due to a misconception of the plates. It is true that in some forms the summit plates are not so readily distinguished as in others, and there are some genera,

* *C. rugosus* appears generally to be a much larger species than *C. pulcher*.

mostly Silurian, of different families, in which the vault is composed of an integument of innumerable minute pieces in which they are undistinguishable, and, in our opinion, do not exist. But we know of no other case of a vault composed of well defined and even ornamented plates, in which in the same genus there was a total absence of plan of arrangement in one species, and well defined summit plates and covering pieces in another. It seemed to us impossible that the summit plates and ambulacra, which were so distinct and conspicuous in the one specimen, should be entirely absent in another species of the same genus; and the only solution of the mystery which we could arrive at, was that in the latter they must be subtegminal, and that the covering of irregular pieces, shown in the four figures above quoted, was broken away in the specimen which exhibited the summit plates.*

As we have said before, we had no opportunity to study the Crotalocrinidae from actual specimens when we prepared the Revision. It required but a single glance at the specimens from Dudley and Gothland coming under our observation lately, to show us that our conception of the structure and relations of *Crotalocrinus*, and its congener, was completely erroneous, and that our views respecting the subtegminal summit plates and double covering are without foundation in the facts. We now renounce them altogether, and all conclusions or arguments based upon the supposed existence of these structures are hereby withdrawn. The same inspection of specimens that disclosed to us our error, revealed with equal clearness the real nature of those plates, and left not the least necessity for inferring the existence of summit plates among the irregularly arranged vaults of Angelin's restorations.

While it is of course unpleasant to be obliged thus to correct descriptions and repair arguments upon which we have laid considerable stress, we regret it in this case the less, because the result at which we have arrived regarding the systematic position of *Crotalocrinus* and *Enallocrinus*, confirms in a most satisfactory manner the validity of the great groups which we have recognized as subdividing

* The references to these figures in Part III of the Revision were unfortunately mixed up in the printing. They should be corrected as follows: on page 64, 7th line from bottom, for "Pl. 6," read "*Pl. 8*," and for "figs. 15 and 25," read *figs. 2 and 15*;" and in the 6th line from bottom, for "Pl. 13," read "*Pl. 8.*" On p. 65, 6th line from top, for "Pl 6," read "*Pl. 8.*" We also misunderstood Angelin's fig. 15, Pl. 25, and Joh. Müllers' fig. 10, Pl. 8, and our references to them should therefore be ignored.

the palæozoic crinoids, and proves that, while the groups themselves are entirely correct, our error consisted simply in a wrong understanding of the family, which led us to assign it to a group to which it does not belong.

Let us now proceed to ascertain to what group *Crotalocrinus* should be assigned.

We established the suborder Articulata to include the group defined by us under the family name Ichthyocrinidae with the addition of *Crotalocrinus* and *Enallocrinus*, (Revision III, p. 140). It is clear from what we now know of their structure, that the two latter cannot remain among the Articulata as that suborder has been defined by us. *

There is no doubt that *Crotalocrinus* possesses some characters belonging to each of the three groups which we introduced in the third part of the Revision. It resembles the Articulata in the peculiar articulation of the arms. In the arrangement of some of its calyx plates it bears a very close relation to the Inadunata, especially *Cyathocrinus*, to which genus J. S. Miller referred it. Like that it has three rings of plates, the upper one including a single anal plate. A casual glance at the structures succeeding these would lead one to think them somewhat similar to the unconnected rays of the Inadunata, but a more careful study will show that they are constructed upon the same principle as the same parts in some groups of the Camarata. They are actually neither true radials nor free arm plates, but, as in the Platycrinidae, represent a transition between them. As in *Platycrinus* there are but two primary radials, the upper one a small triangular axillary, to both sides of which the secondary radials are attached, resting both against its sloping sides and upon the first radial. They are overlaid by the tertiary radials, of which the lower ones often, in a similar way, rest upon the secondary radials and the first primary.

All these plates, in a most peculiar and unique manner, are solidly fitted together with each other and the first primary radial, and have at their ventral face a wide, deep, diverging groove, arched by strong, rigid covering plates, with a large tubular cavity underneath, which in reality forms a part of the cavity of the calyx, like in the free radial appendages in some forms of the Platycrinidae and Actino-

* The actual discovery by us of the disk of *Taxocrinus* with an external mouth, which we have elsewhere described, has settled all debate as to the summit structure of the Ichthyocrinidae.

crinidae. The mode of insertion of the higher radials upon the first primary is similar to that found in *Pterotocrinus* (Pl. XIX, fig. 6), and *Marsupiocrinus* (Pl, XIX, fig. 7, and also Angelin's Pl. XXII, figs. 1, and 28, Pl. XXVII, fig. 4), and is upon the very same principle that prevails in the Platycrinidae generally.

A further striking resemblance to the Platycrinidae is to be observed in the structure of the vault. We give for comparison figures of three of the most perfect vaults of *Crotalocrinus* ever found. Fig. 4, on Pl. XIX is from the Swedish specimen already described as the original of Angelin's Pl. XVII, fig. 3a. Fig. 3 is from a specimen formerly in the Fletcher collection at Dudley, but now belonging to Cambridge University. It differs somewhat from the others in the form of the four smaller orals, which are nearly equilateral instead of clavate, and in having a few more interradials. Fig. 2[b] is from a Dudley specimen in our own collection. We can see enough of the vault in our specimen of *C. pulcher* from Gothland to show that it is built upon the same plan as in the three specimens of *C. rugosus* illustrated, but it cannot be exposed sufficiently to afford a good figure without mutilating the specimen more than is justifiable.

Taking all these facts together, the vault of *Crotalocrinus* seems to have been composed of well developed oral plates (four proximals and a central), large interradials, several anal plates, with anus in form of a subcentral opening or a tube, and covering plates. The latter are solidly inserted in the vault *between* the other plates, so as to form a part of the wall, contrary to the Inadunata, in which the covering plates, and the ambulacra generally, rest *upon the edges* of the other vault plates.

Taking now for comparison the vault of *Marsupiocrinus tennesseensis* (Pl. XIX,fig. 7), we find the same arrangement of orals; the same solid covering pieces incorporated into, and forming part of the vault, originating at the re-entering angles of the five orals, and passing outward to the arm bases; we also find a system of interradial and anal plates substantially like that of the Cambridge specimen of *Crotalocrinus* (Pl. XX, fig. 3). Indeed, if we had the vaults alone of these two specimens under examination, it would not be a very easy matter to point out why they might not belong to the same generic type. Certainly no one can look at the two figures, and not be entirely convinced that they represent the same plan of summit structure. And if we then compare the parts above the first radials

in the two forms, there cannot be the slightest doubt that they belong to the same group, and that that group is the Camarata. It might indeed be fairly said that the calyx of *Crotalocrinus*, in all that determines its subordinal rank, is nothing more than a dicyclic *Marsupiocrinus*. The mode of union of the plates in the dorsal cup is also somewhat similar in the two genera. There are in both of them along the suture lines small conical pits, which penetrate a short distance inward but do not pass through the test (Pl. XIX, fig. 5); the inner half of the apposed faces is peculiarly striated, indicating a sort of syzygial union. On the other hand, the vast multiplication of arms, with their lateral connection into a net-work, constitutes a wide differentiation of this type from any other group of the Camarata, and is without a parallel among crinoids generally. But this is a character which does not affect the fundamental plan of structure, which unites it unquestionably with the Camarata.

Another very remarkable character of this family is the perforation of the higher radials and arm joints by a dorsal or axial canal, which in the higher radials is very large, ramifying to the arms, and in *Crotalocrinus* extends to their extremities. The canals of each ray unite into one on the inner surface of the first radials, and pass downward toward the base. This perforation, and the fact that the arm joints are united also by muscles instead of ligaments only, distinguishes the family sharply from all other Camarata. It was this mainly that led us to place them among the Articulata not knowing the solid structure of the vault. The arms in this group must have possessed a high degree of flexibility, being found sometimes closely folded together lengthwise, often spread out horizontally—even dropping over the calyx—and sometimes compactly inrolled for a considerable distance from the ends, as shown in our figure (Pl. XIX, fig. 1*a*).

There is one point in *Crotalocrinus* which is not clear to us, and on which our specimens do not seem to throw much light. Johannes Müller[1] gives the following description of the ventral structure of the arms. "Dieser Canal [speaking of the ventral furrow along the the arm joints] ist querüber von kleinen Plättchen verdeckt, welche meist alternirend in einander greifen. Zu den Seiten stehen auf der Volarseite der Glieder, die Ambulacra einfassend, äusserst zarte Pinnulae oder schmale Saumplättchen, von denen mehrere (3–4) auf die Länge eines Gliedes kommen. Diese Pinnulae sind unge-

[1] Ueber den Bau der Echinod. Abh. Berl. Akad. d. Wissensch. 1853, p. 189.

gliedert, nur an der Basis scheint sich zuweilen ein Stückchen abzusetzen. Die Höhe der Pinnulae gleicht am breiteren Theil der Hand der Dicke der Glieder."

In the specimens which we have examined, the small alternating plates which cover the ventral furrow are very plainly seen, but we find no trace of the so-called "pinnules or saumplättchen," which were figured and described by Müller and Angelin. It is evident that the alternating *inner* plates, covering the ventral furrow, are the "*saumplättchen*" or covering pieces, and not the *outer* ones along the lateral margins of the furrow, which, if they exist at all, probably are ad-ambulacral plates; they cannot be pinnules in the ordinary sense, for there are, according to Müller, 3 to 4 to each arm-joint. In one of our specimens (Pl, XIX, figs. 1*a*, *b*), high up along the arms, the covering plates are perfectly seen in place, and there appear at their sides in some places, along the margin of the furrows, what seem like serrated edges, several to a joint, and it may be that Müller and Angelin took these edges, which rise somewhat above the level of the covering plates, for pinnules. If these are the structures figured by Müller and Angelin (Bau. d. Echinod. Pl. VIII, figs. 7 and 8; and Icon. Crin. Suec., Pl. XXV, figs. 19, 19a), then the projecting parts are mostly broken away in our specimens, and in all others we have seen.

The arms of the species named by Müller *Anthocrinus Loveni*—but which Angelin considered to be a synonym of *Crotalocrinus pulcher*—were described by him as resembling the five leaves of a flower, which when spread out would not connect, but when closed were folded up, and overlapped each other. It is possible that this is the case in that species, and in fact his cross-section (*Op. cit.* Pl. VIII, fig. 4) clearly indicates it. But we have had before us three specimens from Sweden and one from England, considered to be *C. rugosus*, all having the arms completely spread, in some cases bending downward, and in these the arms are certainly in lateral contact, not only within the rays, but continuously all around. Also the cross-section of the arms of this species, given in Murchison's Siluria (3rd Ed. p. 247, fig. 4a), shows the continuous connection of the arms, and how they fold in upon themselves when closed. The specimen figured in Pl. XX, fig. 4, which, in our opinion, is not *C. rugosus* but an undescribed species, represents a form in which the rays may have been disconnected as in *C. pulcher*. It differs widely from both species in the first radials, which are excavated and have

large, limb-like projections, deeply incurved between the bases of the rays. This form which occurs also at Dudley, associated with *C. rugosus*, is usually labeled as such in collections.

The reticulate arm structure, which distinguishes *Crotalocrinus* from all other crinoids, is its most interesting character. The arms are deeper (from the dorsal to the ventral side) than they are wide, they extend to a great length, and bifurcate just often enough, and at such intervals in *C. rugosus*, to fill up the spaces necessary to form a complete circle with the arms in lateral contact out to the periphery, and the number of branches in the adult specimen, when perfect must have been enormous. In our specimen of *C. rugosus* (Pl. XIX, fig. 1), at the height of the fifteenth joint, there are forty rami to each ray, and this is not more than one third their full length, so that the number of ultimate divisions would amount in this specimen to at least five or six hundred. The joints at the same height are of the same length, and the sutures are in the same line all around, so that they form regular concentric circles. Each joint has two lateral projections given off from the middle part of each side, which meet with those of adjacent branches, forming points of union by which the arms are connected throughout, but leaving open spaces or meshes which produce the reticulate appearance. The arms of *Enallocrinus* resemble those of *Crotalocrinus* in their mode of bifurcation and extraordinary length, but are not connected laterally except for a few of the lower joints. They have, however, frequently, if not always, lateral projections along the joints on each side, and hence possess the cross-shaped arm joints of *Crotalocrinus* (Pl. XIX, fig. $6^{\underline{c, d}}$). The sutures between the joints are also in the same line, and do not alternate as we formerly supposed.

The mode of insertion of the higher radials upon the first radial is very peculiar, and has not hitherto been understood. We might have still remained in ignorance about it, had it not been for the fortunate discovery among our Dudley specimens of an isolated first radial with the succeeding radials attached, so that we could see them from all sides (Pl. XX, fig. 4). By the aid of this, and a very interesting, much weathered specimen, loaned us by Dr. Lindström, we are enabled to describe and illustrate the position of these parts quite satisfactorily. The plates from the second radial up are of considerable size, but they are not always visible on the dorsal side. In *C. pulcher* they are plain enough (Pl. XX, fig. 1), but in *C. rugosus* they often appear as mere points or thin edges

(Pl. XX, fig. 2^{a}). The other ends emerge upon the ventral side, where they present a considerable surface, containing a large ambulacral groove. In order to attain this position, the plates, which are wedge-shaped, bend inward and upward until their opposite ends stand nearly at right angles to each other, and the arms at their origin pass out in a horizontal position. This can be seen in fig. 2^{c} Pl. XIX, which represents a vertical section, giving a side view of the same succession of plates as is shown dorsally by fig. 2^{a}, and ventrally by fig. 2^{b} on the same plate. The successive pieces are numbered in each figure to correspond, and by comparing them, and remembering that they present three different views of the same elements, we think there will be no difficulty in understanding them. We cannot see the least evidence of mobility of these plates until they become free from the first radial, and thus attain the rank of arm plates. Whenever the arms are found folded up, the bending from a horizontal to a vertical position takes place in the lower arm plates, and not in the higher radials. The lanceolate areas, which are such a conspicuous feature of the ventral surface, and extend from the second axillary to the fifth or sixth bifurcations, are formed by a great thickening along the outer edges of the marginal plates of two adjacent rays, and therefore consist of two rows of arm plates, respectively radials, decreasing in width in their upward arrangement.

The anus is excentric, and in *C. pulcher* takes the form of a large tube, while in all authentic specimens of *C. rugosus* it seems to be a simple opening. The form and position of the tube have been wrongly described by us. Angelin's beautiful looking figure, purporting to show it to its full length (Icon. Crin. Suec., Pl. XVII, fig. 1), originating at the edge of the calyx, and lying outside the arms, proves to be an ideal figure, based upon the erroneous interpretation of some fragmentary pieces. Our specimen (Pl. XX, fig. 1^{b}) shows the base of the tube very well, but not its full length. To judge from the fragments, shown by Angelin's Pl. XXV, figs. 8—13, it must have been of considerable length in some specimens. It seems to have been somewhat more highly organized than the anal tube of the Camarata generally, and to approach the ventral sac of the Fistulata. The actual length has not been observed, but from the manner in which the large cavity within tapers in different specimens, we have no doubt that the opening is at the upper end, and

represents a true anal tube, whatever other function it may have possessed. Nothing is known of the anal opening of *Enallocrinus*.

We give herewith new definitions of the Crotalocrinidae and their two genera *Crotalocrinus* and *Enallocrinus*, to take the place of those given by us in the Revision, Part III, p. 143, and pp. 147—152, and we request all who may be using the Revision to substitute them at once.

We now direct attention to another point of considerable interest which has been developed by this investigation. A very perplexing figure was given by Angelin (Pl. XVII, fig. 2b), and a somewhat similar one by Murchison (Siluria, 3rd Ed., p. 247, fig. 5), which show certain extensions apparently from the inner rim of the first radials, and which superficially resemble the so-called "consolidating apparatus" of *Cupressocrinus*. A closer examination of Angelin's figure shows these extensions to be composed of small plates; both figures, however, are misleading, for our specimens show that the plates forming those extensions do not rest against the inner edges of the first radials as represented, but upon their upper faces, as correctly shown in Angelin's Pl. XVII, fig. 2a. They are nothing but the exposed ventral surfaces of the second primary and succeeding radials, the elevations being the projecting margins along the ambulacral grooves. Neither do they extend so far inward as would seem from Angelin's figure, they project inward only for a short distance, and form underneath a surface of attachment for certain organs hereafter described.

Müller described and figured correctly (*Op. cit.* p. 189, Pl. VIII, fig. 5), the inward curvature of the plates, but we cannot agree with him in his statement that by means of this curvature a roofing is formed over the periphery of the calyx. This is not confirmed by the specimens, in which the calyx is covered by summit plates, interradials, etc., and the grooves around the periphery are roofed over by solid covering plates—leaving only the lateral margins exposed —in connection with, and forming part of the calicular cavity. The structure is clearly seen in our fig. 1[a], Pl. XIX, in which the grooves are shown open except in one ray, where the covering plates are restored from the same part in another specimen.

Another figure of Angelin (Tab. VII., fig. 7a) gives an inner view—that is, from below; not "*superne visus*," as erroneously stated in the explanation of the plate—of a specimen of *C. pulcher* of which he speaks as showing the so-called "consolidating apparatus."

Carpenter in his paper on Crotalocrinus[1] explains that "the calyx is broken across near the level of the top of the basals, so that the internal faces of the radials and the following plates are exposed to view, with the remarkable striations upon them, which were regarded by Angelin as corresponding to the consolidating apparatus of *Cupressocrinus*," and he proceeds: "It is possible that, like this structure, they may represent an uneven surface for the attachment of muscles and ligaments, but whatever else they may be, the striæ are certainly not hydrospire slits, as supposed by Wachsmuth and Springer in 1879 * * * *. But in any case they will no longer be able to refer to this family as Palæocrinoids which 'probably have hydrospires within the calyx,' and to use this supposed fact as an illustration of their theory that Blastoids, Cystids and Crinoids are so closely linked together that they are not entitled to rank as Classes of Echinoderms equivalent to the Urchins and Starfishes."

We have been able to study the organs in question in our specimen from Gothland (Pl. XIX, fig. 1), and in two of those used by Angelin, loaned to us from the National Museum of Stockholm, in all of which they are very well shown. They are totally different structures from the so-called consolidating apparatus of *Cupressocrinus*, which we regard as muscle plates for the attachment of muscles and ligaments to move its huge arms. The muscle plates of *Cupressocrinus* are appendages of the first radials, and form part of the upper surface of the vault, similar to the muscle plates of *Symbathocrinus*, in which we know from direct observation that they constitute parts of the vault, only the central space being closed by additional plates. In both genera those plates are apposed by corresponding faces upon the first brachials, and there is no roof or covering of any kind above them, they being necessarily external if they served for places of muscular attachment to move the arms. The case is totally different in *Crotalocrinus* in which the parts in question are roofed over by very solid covering plates, leaving little more than the faces forming the lanceolate areas exposed. Angelin applies the name "consolidating apparatus" not only to the overhanging margins of the radials, but also to the lamellæ underneath, to which Carpenter refers as "remarkable striations," possibly for "the attachment of muscles and ligaments." These so-called striations consist of parallel lamellose walls or partitions, located in regular sets within chambers or recesses, which underlie partly

[1] Op. cit, p. 406.

the overhanging margins of the higher radials constituting the lanceolate areas, partly the outermost interradial, and are limited on either side by the inward extensions of the second and succeeding radials. There are two sets of these lamellæ to each interradius, those of adjacent rays meeting laterally and entering the same chamber where they are closely connected; while those of the same ray stand at an angle from each other, and are apparently disconnected except by a mere point. Each set is composed of five to seven folded lamellæ, with continuous walls forming loops at each end. They stand upright, and seem to be attached at their lower ends to the inner surface of the first radials, and those in the same ray come together by their upper ends at a small angle under the small triangular second radial, where it projects farthest inward. The upper ends are further attached along the inner walls of the higher radials and the outer interradials, underneath which the two adjacent sets meet by parallel plates and form a close connection. The arrangement at the anal side is not clearly shown in any of the specimens. In *Enallocrinus* we have not been able to discover anything of the lamellæ, but we had for examination but a solitary specimen showing the interior of the calyx. There are seen, however, the same chambered spaces in which they might rest, and we have little doubt they existed in that genus also. Their position and structure in *Crotalocrinus rugosus* are shown in our figures 1^{a} and 1^{b} on Plate XIX.

From our description it must be clear that these laminated structures do not possess any of the characteristics of muscle-plates. Their position in paired sets is interradial; they are completely internal, and have no visible connection with the arms, nor do they present any surface for the attachment of muscles or ligaments; but on the contrary are very frail structures, having in some places little partitions connecting the walls, and giving the whole a somewhat porous appearance. On the other hand if we compare them with the hydrospires in the Blastoid genus *Orophocrinus*, one cannot help being struck with the resemblance in form, position and arrangement. We will not assert unqualifiedly that they are hydrospires, but we are very confident that they are not muscle-plates, nor anything of that nature, and if they are not of the same character as the similar organs in *Orophocrinus*, which have been universally considered to be hydrospires, then we must acknowledge ourselves completely at a loss for anything in echinoderm morphology with which to compare

them. There is nothing else like them in any known crinoid. If they are hydrospires, then they certainly do afford a strong illustration of the close alliance between Blastoids, Cystids and Crinoids. If they are not hydrospires, we should like to know what they are.

Enallocrinus is evidently very closely allied to *Crotalocrinus*. The genus occurs at Dudley, England, whence we obtained specimens showing the arms better than the Swedish ones, but nevertheless our material for the study of this type was by no means so satisfactory as that of *Crotalocrinus*. The English specimens are all more or less crushed, and do not throw much light on the structure of the calyx.

Angelin's figures purporting to show the vault are imaginary, as we have before shown. The only specimen in the Stockholm Museum showing any part of the ventral covering has been sent to us for examination, and we give two views of it (Pl. XX, figs 5 $\frac{a, b}{}$). It is somewhat abnormal, two of the rays being grown together in such a way as to modify the arrangement of some of the plates. It is one of the specimens from which it is supposed Angelin's figure 3a, Pl. VII was constructed. The insertion of the higher radials upon the first radials is upon the same plan as in *Crotalocrinus*, especially the species shown by Angelin's Pl. XVII, fig. 3a, and our Pl. XX, fig. 4, and from this, and what little we can see of the ventral covering in the specimen above alluded to, we conclude that the vault must have been constructed substantially like that of *Crotalocrinus*.

We figure a flattened specimen from Dudley (Pl. XX, fig. 6^{a}), which shows the arrangement and bifurcations of the arms, but not by any means to their full length. We have another set of arms which seem to have their filiform extremities nearly complete, and from this we should infer that the specimen we have figured shows but little over half the length of the arms. Figs. 6^{c} and 6^{d} illustrate the projections from the sides of the joints, in the same specimen. We consider them important characters, perhaps representing the projections on the arms of *Crotalocrinus*, and indicating a tendency toward the reticulate arm structure, which is the only well marked distinction between the two genera.

The specimen represented by Angelin's Pl. XV, figs. 1, 1a, and 2, as *Enallocrinus assulosus*, and which Dr. Lindström assures us is correctly figured, represents in the reduced lateral connection of the arm bases, and the presence of small interradials on the dorsal side,

a considerable departure from the typical form of the genus. It is inconsistent with the generic definition of Angelin, who described it as having "*interradialia nulla.*" It is a variation in the direction of the English form of *Marsupiocrinus—M. coelatus*—(Pl. XX, fig. 7), which differs in its dorsal interradials from *M. tennesseensis* in almost the same way.

Crotalocrinus and *Enallocrinus* form a good family, which is connected through *Marsupiocrinus* [1] with the other Camarata.

Suborder CAMARATA.

Family CROTALOCRINIDAE.

Base dicyclic, symmetry bilateral. Calyx throughout composed of rigid plates. Dorsal cup constructed almost exclusively of underbasals, basals, the first radials, and a small anal plate. Higher radials up to the third or fourth order irregularly wedge-shaped, their sharp ends directed outwards or sometimes hidden from view, their larger ends, which curve upwards, grooved for the ambulacra. The plates rest partly upon the first radials, partly against the radials of the preceding order, being with the former, and with one another, and laterally with those of adjoining rays, firmly united by suture. Arms capable of great mobility; uniserial; long; dividing into very numerous branches, which are free, or connected laterally by tissues so as to form a net-work around the calyx, either continuous, or limited to the rays and forming five reticulate leaf-like arms. The arm branches are perforated by large axial canals, which penetrate also the higher radials.

Ventral surface of calyx flat, composed of five unequal orals—the posterior one the larger—five radial dome plates, one or more interradials, and several series of covering pieces which take the rigid form of vault plates.

Column large, round; central cavity extremely large.

CROTALOCRINUS Austin.

1842. Austin, Ann. and Mag. Nat. Hist., Ser. 1, Vol. X, p. 109.
1843. Austin, ibid., Ser. 1, Vol. XI, p. 198.
1848. Morris, Cat. Brit. Fos. (Ed. 1), p. 50; (Ed. 2), p. 75.

[1] It is an interesting fact as showing the keen perception of that veteran English naturalist, that Th. Austin in 1843 (Ann. and Mag. Nat. Hist. Ser., II, Vol. XI, p. 198) referred *C. rugosus* to the Marsupiocrinidae, a family named, but not defined by him.

1854. Salter, apud Murchison, Siluria, (Ed. 2), p. 219; (Ed. 3), p. 247, figs. 4, 5, 6, 7.
1855. McCoy, Brit. Pal. Foss., p. 54.
1873. Salter, Cat. Mus. Cambr., p. 123.
1878. Angelin, Icon. Crin. Suec., p. 26, Pl. 7, Pl. 8, Pl. 17, Pl. 25.
1879. Zittel, Handb. d. Palæont., I., p. 356, fig. 244.
1882. De Loriol, Pal. de France, tome 11, Crin., p. 51.
1886. Wachsmuth and Springer, Rev. Palæocr., Pt. III., p. 165.
1886. P. H. Carpenter, Ann. and Mag. Nat. Hist. for November, p. 397.

Syn. *Cyathocrinus*, 1821, J. S. Miller, Nat. Hist. Crin., p. 89, with plate; *Anthocrinus*, 1853, Joh. Müller, Abh. Akad. Berlin, pp. 188–192, Pl. 8;
1855. Roemer, Lethæa. Geogn. (Ausg. III), p. 255.
1855. Quenstedt, Handb. d. Petref., IV, p. 943, Pl. 75.
1857. Pictet, Traité. de Paleont., IV, p. 312, Pl. 100.
1860. Bronn, Klassen. d. Thierreichs., (Actinozoa), Pl. 27.
1862. Dujardin and Hupé, Hist. Nat. Zooph. Echinod., p. 117.

GENERIC DIAGNOSIS.

When the arms are closed the crinoid resembles an elongate bud with folded leaves; when these are spread, it is wheel shaped, with five lanceolate areas between the bases of the rays. Calyx subglobose, flattened above.

Underbasals 5, large, pentangular, of uniform size. Basals 5, very large, extending three fourths the height of the calyx, all hexagonal except the posterior one, which is higher and has the upper angle truncated for the reception of a comparatively small, quadrangular anal plate, which rests between the first radials.

First radials much wider than high, their distal faces thickened, either concave or straight, and occupied by small, shallow depressions for the reception of the second and higher radials, which to the third or fourth order rest partly upon this plate. The second radial occupies a very small space at the middle of the first, where it appears as a small, trigonal bifurcating plate, sometimes scarcely visible dorsally. From its dorsal or outer side to its ventral side, the plate is very long and slender, bent upwards almost to a right angle, so as to bring the face opposite to that exposed dorsally into a horizontal position, and on a level with the vault. The secondary radials rest against the sloping faces of the second primary, and upon the first; they are bifurcating plates, and as such support immediately the ter-

tiary radials, which in *C. rugosus*, sometimes together with the first plate of the fourth order, rest partly upon the first radial. All of these plates, in various ways, are firmly attached to the first radial, and united suturally with one another, and all of them, by curving upwards and inwards, extend from the dorsal to the ventral surface of the calyx, forming as such a sort of transition between true radials and arm plates, in a similar manner as the higher radials of the Platycrinidae, which they resemble in their arrangement. The plates are wedge-form, thinning out toward the dorsal cup, where they are seen as mere points or lines, or one or more of them are invisible altogether. Their larger upper faces, which are exposed ventrally, are deeply grooved for the reception of the ambulacra, and, when the covering plates are in position are only partly exposed. The plates above the fourth order are not in contact with the first radials, and may be regarded as true arm-plates, which they resemble in form and in point of mobility.

The arms are long and branch frequently; they are connected laterally by points of attachment from near the middle of each joint, with open spaces between them, forming together a sort of network around the calyx with innumerable elongate meshes. In *C. rugosus* the network is continuous around the calyx, but in *C. pulcher* the rays are separated, and form five broad reticulate leaves, which, when closed over the calyx, overlap each other, contrary to the case of *C. rugosus* in which the undivided network is closely plicated and folded. The lower plates of the rays, to the third or fourth order, are immovably connected among each other and with the first radials; but higher up in the rays, where the plates are no longer in contact with the first radials, an articulation by strong muscles and fossæ takes the place of suture. The arm joints, owing to their lateral projections, have the form of a cross with short arms: they are long flat on the dorsal surface, laterally compressed, with straight sides, and deeply grooved on the ventral surface for the reception of the ambulacra.

The ambulacral furrows are arched by covering pieces, 3 to 4 to each side of the arm joint, alternately arranged. The arm joints are disposed in regular dichotomizing longitudinal rows, as well as in regular concentric transverse rows, the points of union occupying the same line all around. Each arm plate is pierced with a very large dorsal canal, and the bifurcating ones with two, which meet in the middle of the plate; they ramify to the ends of the arms,

and all converge into one in the second radials, thence passing downward along the inner surface of the first radials toward the basals. The bifurcations near the calyx are unequal, the sloping faces of the axillaries next the outer margins of the rays being considerably wider than the inner ones, and the plates which they support are as large in proportion. This continues on to about the sixth axillary, above which the bifurcations gradually become regular, and the outer plates attain the same width as the inner ones. By this peculiar arrangement there appear, when the arms are spread, along the outer plates of adjacent rays, five well marked lanceolate areas, to the top of which the rays remain in lateral contact. The bifurcations along the arms are extremely numerous, and take place at various intervals, sufficient to fill up the full segments of the circle when the arms are extended; they taper but slightly, are very long, and become thread-like at the ends.

The higher radials from the first primary up project inwards, beyond the periphery of the calyx; the second projects the farthest, and the plates of the second order slope away from it, as also those of the third. The latter form the proximal ends of the lanceolate areas whose overhanging margins, together with the outermost interradial, form a roof, under which are located five large recesses or chambers, interradial in position, each of which is occupied by two sets of laminated structures, in form and arrangement closely resembling the hydrospires of the Blastoid genus *Orophocrinus*. Each set apparently is composed of five to seven folded lamellae with continuous walls and loops at each end; they stand upright, face laterally the inner walls of the overhanging primary radials, their upper ends attached to the inner floor of the outer interradial, being thus completely covered by vault structures.

Vault flat, on a level with the spreading arms; composed of five oral plates (the so-called central plate and the four large proximals). The posterior oral (central plate) is large, somewhat elongate, its anterior end resting between the truncate faces of the four others, the posterior end againt small anal plates. The four small orals vary from elongate-clavate (Pl. XX, figs 2^b and 4) to almost regularly hexagonal (Pl. XX, fig. 3). Outside the orals, and alternating with them, are five somewhat irregular radial plates, which are axillary, giving off two sets of covering pieces, two rows of plates to each set, all in lateral contact; they are heavy, convex plates, a little wider than high, alternately arranged, and solidly inserted into the vault.

Between the covering plates, and abutting against the four smaller orals, are two or more interradials, the inner ones the larger. Between the radial-dome-plates, and against the large posterior oral, are numerous small anal plates which embrace the anus, and of which the outer ones face the anal plate of the dorsal cup. The anus is excentric, and its form varies among species, being either extended into a tube, or placed at the top of a small protuberance. The tube apparently reached considerable length, and seems to have been composed of several rows of transverse pieces longitudinally arranged, with a large octagonal cavity.

Column very large; terminating in numerous rootlets. Canal large, round.

Geological Position, etc. Upper Silurian of England and Sweden.

List of Species:—

1840. *Crotalocrinus pulcher* Hisinger, (*Cyathocrinus pulcher*), Leth. Suec., Supp. II., p. 6, Pl. XXXIX, figs. 5 a. b.–1878, Angelin, Iconogr. Crin. Suec., p. 26, Pl. VII, figs. 5—7 a, b; Pl. VIII, figs. 1—9a; Pl. XVII, figs. 1, 1a—d; Pl. XXV, figs. 8—20.—1879, Zittel, Handb. d. Palaeont., Vol. I, p. 357, figs. 2, 4, 4 a—e.—1886, W. and Sp., Revision Palæocr., Pt. III, p. 150.

Syn. *Anthocrinus Loveni* Joh. Müller, 1853, Abh. d. Berl. Akad. d. Wissensch., p. 192, Pl. VIII, figs. 1—11.—Pictet, 1857, Traité de. Paléont., Vol. IV, Pl. c, figs. 8 a, b, c.—Dujardin and Hupé., Hist. nat. Zooph. Echinod., p. 117.—Quenstedt, 1885, Handb. d. Petrefactenk., IV, p. 943, Pl. 15, fig. 4.

Upper Silurian, Gothland, Sweden, and Dudley, Eng.

1821. *Crotalocrinus rugosus* Miller, (*Cyathocrinus rugosus*), Nat. Hist. Crin., p. 89., with plate.—1837, Hisinger, (*Cyathocrinus rugosus*), Leth. Suec., p. 89, Tab XXV, fig. 3; also Antckn, Heft IV, p. 217, Pl. VII, fig. 3.—1839, Phillips (*Cyathocrinus rugosus*), Murchison's Silur. System, p. 672, Pl. 18, fig. 1.—1843, Austin, Ann. and Mag. Nat. Hist., Ser. 1, Vol. XI, p. 198.—1843, Morris, Cat. Brit. Foss., (Ed. I), p. 50.—1850, D'Orbigny, (*Cyathocrinus rugosus*), Prodr. d. Paléont., Vol. I, p. 46.—1854, Salter, apud Murchison, Siluria, (Ed. 2), p. 219, (Ed. III, p. 247), figs. 4—7, and Pl. 13, fig. 3.—1855, McCoy, Brit. Pal. Foss., p. 55.—1873, Salter, Cat. Mus. Cambr., p. 123.—1878, Angelin, Icon. Crin. Suec., p. 26, Pl. VII, fig. 4; Pl. XVII, figs. 8, 8a. (not figs. 3, $3^{a,b}$).—1879,

Zittel, Handb. d. Palæont., I., p. 357, fig. 244.—1885, Quenstedt, (*Cyathocrinus rugosus*), Handb. d. Petrefactenk., IV, p. 943, fig. 349.—1886. W. and Sp., Rev. Palæocr., Pt. III, p. 150.

Upper Silurian. Gothland, Sweden and Dudley, Eng.

1878. *Crotalocrinus superbus* Angelin, Iconogr. Crin. Suec., p. 26, Pl. XVII, figs. 2, 2a, b.—1886, W. and Sp., Rev. Palæocr., Pt. III, p. 150.

Upper Silurian. Gothland, Sweden.

Crotalocrinus (undescribed species). Pl. III, fig. 4 (Referred by Angelin, Pl. XVII, figs. 3, 3a, b, to *C. rugosus*).

Upper Silurian. Gothland, Sweden and Dudley, Eng.

ENALLOCRINUS D'Orbigny.

1850. D'Orbigny, Prodr. d. Pal., 1., p. 46; Cours. élém., II, p. 142.
1854. Salter, apud Murchison, Siluria, (3rd Ed.), p. 247.
1857. Pictet, Traité d. Pal., IV., p. 320.
1862. Dujardin and Hupé, Hist. nat. Zooph. Echin., p. 134.
1878. Angelin, Icon. Crin. Suec., p. 25.
1879. Zittel, Handb. d. Pal., I., p. 356.
1886. Wachsmuth and Springer, Rev. Palæocr., Pt. III, p. 150.

Syn. *Apiocrinites* (Hisinger) in part;
Millericrinus (D'Orbigny) in part; *Anthocrinus* (Quenstedt) in part.

Generic Diagnosis.—Calyx similar in form and construction to that of *Crotalocrinus*; interradials sometimes appearing dorsally. Arms not reticulate.

First radials wide, their distal faces usually occupied by a deep lunate excavation in which the second primary and one or two higher radials rest; sometimes, however, truncate. Second primary and higher radials inserted and connected as in *Crotalocrinus*, curving upward and appearing on the ventral side in a similar way. Rays completely disconnected from the first radials up, and the arms becoming free variously between the first to the fourth bifurcation. Second radials perforated by a large axial canal which passes downward; it ramifies within the higher radials, and passes into the arms, but apparently does not extend to their full length.

Arms uniserial, very long, tapering little, bifurcating at lengthening intervals toward the upper parts into very numerous equal branches, the ultimate divisions being extremely attenuate; the arms capable of being spread out horizontally. Arm joints shorter than in *Crotalocrinus*, with parallel sutures; those of adjacent branches

opposite each other not alternating. Toward the upper ends of the arm joints there are more or less conspicuous transverse projections —one from each side of the joint—which are more prominent and elongate at the ventral side. They border the arm furrow, and give to the arm, when viewed from the side, a pectinate appearance, which is more strongly marked toward the distal ends of the arms (Pl. XX, figs $6^{b,c}$). Ambulacral furrows shallow, with covering plates arranged in the usual way.[1]

Vault apparently similar to that of *Crotalocrinus*; median part unknown; ambulacra toward the periphery roofed over by convex alternating pieces having the form of vault plates, which pass out over the arms. Anal opening unknown.

Column round, very large, with short joints and thin walls; canal round and of extremely large size.

Geological Position, etc. Upper Silurian of Sweden and England.

List of Species:—

1878. *Enallocrinus assulosus* Angelin, Icon. Crin. Suec., p. 26, Pl. XV, figs. 1—4. Upper Silurian, Gothland, Sweden.

1828. *E. scriptus* Hisinger (*Cyathocrinites*?), Anteckn IV, p. 217; Pl. V, fig. 9; Pl. VII, fig. 1.—1831. (*Apiocrinites* (?) *scriptus*), Anteckn V, p. 123, Esquisse d'un tableau des Petref. de la Suède, p. 23.—1837. Leth. Suec., p. 89, Pl. XXV, figs. 1 and 2.—D'Orbigny, 1840 (*Millericrinus scriptus*), Hist. Nat. Crin., p. 94, Pl. XVI, fig. 29.—1850. Prodr. d. Pal., I, p. 46.—Angelin, 1878, Icon. Crin. Suec., p. 25, Pl. VII, figs. 1—3a; Pl. IX, figs. 18 and 19; Pl. XXV, figs. 1—7; Pl. XXVII, figs. 17—20a.

Syn.—*Enallocrinus punctatus* Hisinger, Leth. Suec., p. 89.—*Millericrinus punctatus* D'Orbigny, Hist. Nat. Crin., p. 94, Pl. XVI, fig. 30.—*Enallocrinus punctatus* Salter, apud Murchison, Siluria, (Ed. 2), p. 218.—*Anthocrinus scriptus* and *A. punctatus*, Quenstedt, Handb. d. Petref., IV, p. 944, Pl. 75, figs. 6, 7.

Upper Silurian. Gothland, Sweden and Dudley England.

[1] We have observed these projections on the arms only in the English specimens. We give it as a generic character, as we think it likely the Swedish ones will show it also when sufficiently well preserved; and because we consider it of some importance, as representing the projections on the arms of *Crotalocrinus* by which these were connected, and thus exhibiting a tendency toward the reticulate structure.

Explanation of Plates.

Plate XIX.

Fig. 1^{a}. *Crotalocrinus rugosus.* Ventral aspect of a large specimen from Sweden, showing the inner floor of the calyx, the lanceolate areas, and the outstretched arms with their deep ventral grooves, and in places their covering pieces; the tips of the arms coiled up so as to expose their dorsal face. The covering pieces at the lower right hand corner restored from another specimen.

(Collection of Wachsmuth and Springer.)

Fig. 1^{b}. Oblique view of a portion of the same specimen, showing the lamellae beneath the overhanging margins of the higher radials.

Fig. 1^{c}. Ventral view of a portion of the arms enlarged.

Figs. $2^{a, b, c}$. Diagramatic figures showing the arrangement of the higher radials in *Crotalocrinus rugosus*; 2^{a} the dorsal side; 2^{b} the ventral side; 2^{c} a vertical section through the dotted line in 2^{b}. The numbers refer to the same plates in all three figures, i. e. 1^{1} and 1^{2} to the first and second primary radials, 2^{1} to the secondary radials, 3^{1} and 3^{2} to the tertiary radials, 4^{1} and 4^{2} to the quaternary radials; the succeeding plates are brachials.

Fig. 3. Ventral aspect of the same species from a specimen in the National Museum of Stockholm, showing the rigid covering plates around the margin of the calyx.

Fig. 4. A portion of a first primary radial of the same species with the higher radials in place resting upon it.

(Collection of Wachsmuth and Springer.)

Fig. 5. Enlarged view showing the markings on the lower face of a first radial of the same species.

Fig. 6. Radials and lower arm plates in *Pterotocrinus.*

Fig. 7. The radials and lower arm joints in *Marsupiocrinus tennesseensis.*

Plate XX.

Fig. 1^{a}. *Crotalocrinus pulcher.* Anterior view of a specimen with arms from Gothland, Sweden.

(Collection of Wachsmuth and Springer.)

Fig. 1^{b}. Posterior view of the same specimen, showing the base of the proboscis.

Fig. 2^{a}. Calyx of a small specimen of *Crotalocrinus rugosus* from Dudley, England.
(Collection of Wachsmuth and Springer.)

Fig. 2^{b}. Ventral aspect of the same specimen.

Fig. 3. Ventral aspect of *Crotalocrinus* sp.?
(Drawn from a gutta percha cast. Original in the Museum at Cambridge, England.)

Fig. 4. *Crotalocrinus* sp. und., from Sweden. Ventral view, from a fine drawing by Mr. G. Liljevall. (Original in the National Museum at Stockholm).

Fig. 5^{a}. *Enallocrinus scriptus.* Posterior view of a specimen from Sweden in the National Museum at Stockholm. 5^{b}. ventral view of same specimen, showing portions of the covering plates in some places; the middle of the vault broken away.

Fig. 6^{a}. *Enallocrinus scriptus.* Anterior view of a nearly complete specimen from Dudley, England (Collection of Wachsmuth and Springer), 6^{b}. transverse section of column of same specimen, showing the large central canal; 6^{c}. enlarged side view of a portion of the arm, showing the pectinated projections; 6^{d}. Dorsal view of same.